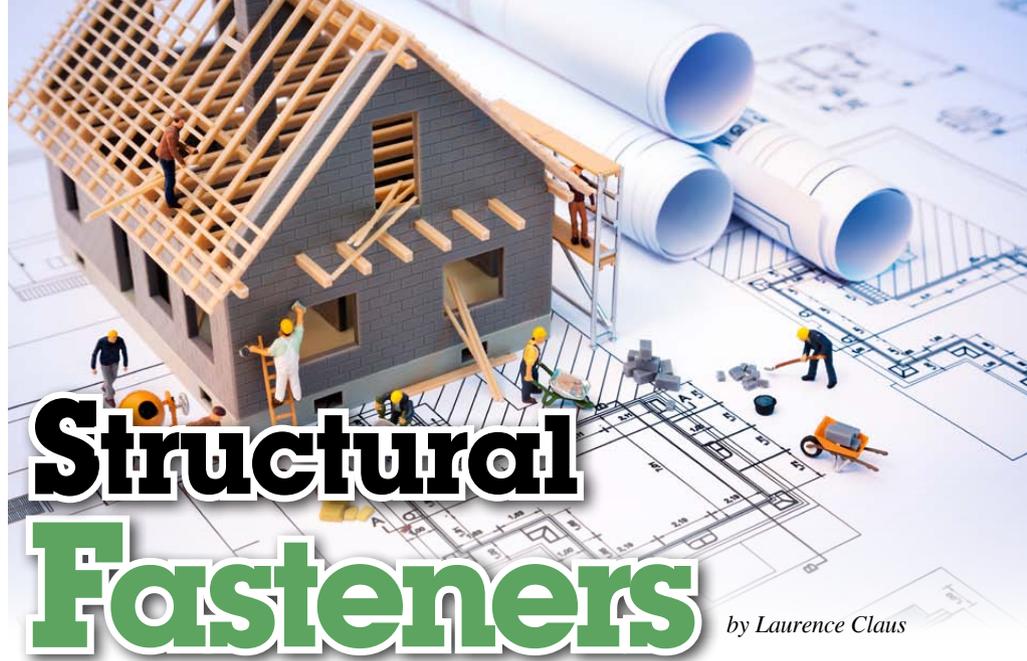


**F**asteners come in all sorts of shapes, sizes, and designs and are used in nearly everything. Although there is so much diversity of product, manufacturers and purveyors of fasteners generally only specialize in focused segments of the market. This is why a manufacturer specializing in automotive fasteners may be entirely unknown in the aerospace or construction fastener segment. Thus, each fastener market segment remains insular and with a relatively small group of players. Once inside those smaller market segments, it often breaks down even further. Take for example automotive fasteners, the overall segment is served by dozens of players, but when it comes to internal engine components, that number dwindles to maybe a handful.

In the same way, as one considers the construction fastener industry, there are many players considered to be in the construction fastener business but each seems to specialize in limited areas of expertise. Perhaps one of the most critical of these “segments in a segment” is Structural Bolting. These are the workhorse fasteners that we daily rely on to hold together and support the buildings we work in, infrastructure we use, and bridges we cross. In sheer number, structural fasteners represent only a small fraction of the total fasteners produced and used every year, but arguably represent some of the most critical and important.

When speaking about the segment, Structural Bolting seems a perfectly adequate description. However, considering the segment in light of the components this term can be misleading, as it seems to suggest the segment is only about bolts. In fact, unlike almost all other fasteners, **structural fasteners are sold as finely tuned assemblies that include a bolt, nut, and one or more washers.** They come in containers already preassembled and lubricated. Users are thoroughly trained and mandated to use careful storage, installation, and assembly practices.

Structural Bolting, although seemingly pretty simple, is not. There is a great deal of engineering and expertise associated with this topic. Purveyors of these products have experts or access to experts that are very knowledgeable in the specific engineering related to structural bolted joint. In fact, this small segment of the fastener industry probably has more Professional Engineers, PhDs, and university professors sharing their expertise than any of the other, larger fastener segments. Although many thick



books exist on the subject and it would be impossible to synthesize that all in a short article, this article will attempt to provide a glimpse into this interesting world of structural fasteners and provide a high level overview of the topic.

### What are Structural Fasteners?

Unlike normal fastener procurement where one separately purchases or produces just the needed externally threaded, internally threaded, and washer components required to complete the joint, structural bolting applications are almost always comprised of a free spinning bolt, nut, and washers. To guarantee that they perform as advertised they are preassembled into structural bolt assemblies and carefully packaged in sealed containers.

**In application, most structural bolts either exclusively or predominantly experience shear loading.** Although there certainly are applications where these fasteners are loaded in tension, the majority are intended for shear applications. Of course this makes sense when one begins to consider where these fasteners are used. Most are used in steel and iron structures, to hold beams and girders that primarily support downward gravity loads in-place. (See **Figure 1**) These fasteners, therefore, are loaded perpendicular to the load direction, and are, thus, in shear. Additionally, these fasteners often squeeze multiple components together that must not move. Structural joints, therefore, are often described as



Figure 1

“Slip Critical” and “Non-Slip Critical” joints. Slip critical joints must develop large amounts of friction between contacting surfaces (in this field known as the Faying Surface) so that they cannot and will not move or slip relative to each other. Non-slip critical joints rely on the bolts to act like shear pins and simply bear the load.

In either case of shear loading and where the joint is loaded in tension, achieving the maximum safe Preload is often the most desirable outcome. Therefore, most structural connections are critical connections, which is why most structural fasteners are sold as assemblies. These assemblies have been tested to assure they achieve the desired Preload prior to arrival at the jobsite and are again recertified on the job site just prior to use. Although normally without the benefit of expensive, high precision installation tools like one finds in automotive and airplane assembly plants, iron workers get trained in proper installation methods, which, when properly followed, provide remarkably consistent installation control.

Structural Bolts are different from bolts designed for general application in two important ways. First the heads sizes are different. **They have been designed so that the hex size on the bolt head and the nut are identical.** This benefits the installer because their wrench or socket will fit on either the bolt head or nut. The second significant difference is in the unthreaded body length. Although there are a couple of exceptions, **structural bolts have shorter threaded length than general purpose bolts.** At first blush the reason for this may not be immediately obvious. Recall that most structural bolts are loaded in shear. Therefore, it is highly advantageous to have as much, and preferably all, of the thread (which is weaker than



the full body in shear) outside of the shear plane. By controlling the body length it is possible to completely exclude the threads from the shear plane. Even if it is impossible to entirely exclude the thread, tighter manufacturing controls on the body and threaded lengths allows for only a small percentage or, perhaps, just the thread run-out to be in the shear plane, negating a significant vulnerability if most of the thread is in the shear plane.

**Structural fasteners have their own standards. In the structural fastener world there are essentially three different standard types that are important. First there are the Product (or Dimensional) standards. This is ASME B18.2.6 (current revision 2019), "Fasteners for Use in Structural Applications". Second are the Material Standards. There are several that fall in this category, although the most predominant is ASTM F3125/F3125M (current revision 2019), "High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, Inch Dimensions 120 and 150 ksi..." The final standard is the Research Council on Structural Connections' "Specification for Structural Joints Using High-Strength Bolts".**

### ASME B18.2.6:

ASME B18.2.6 is the Product Standard for Structural Fasteners. It addresses the dimensional and refers to the appropriate Material Specification for five different products.

1. Heavy Hex Structural Bolts
2. Heavy Hex Nuts
3. Hardened Flat Washers
4. Compressible Direct Tension Indicating Washers (DTI)
5. Twist off Bolts

Section 2 of this standard provides the detailed dimensional and general information required to produce Heavy Hex Structural Bolts. The most significant difference from general purpose bolts is the head height is a little shorter and the length tolerances related to the full body diameter are tighter. The Material Standard referenced with these products is ASTM F3125/F3125M Grade A325, Grade A325M, Grade A490, and Grade A490M.

Section 3 of this standard provides detailed dimensional and general information required to produce Heavy Hex Nuts. These exhibit essentially the same dimensional requirements found in general purpose Heavy Hex Nuts. The Material Standard referenced with these products is ASTM A563 and ASTM A194/A194M.

Section 4 of this standard provides the detailed dimensional and general information required to produce Hardened Flat Washers. The standard provides for two different types, round, flat washers and square, beveled washers. The Material Standard referenced with these products is ASTM F436/F436M.

Section 5 of this standard provides detailed dimensional and general information required to produce Compressible Direct Tension Indicating Washers. These washers are a unique innovation utilized mostly in structural bolting to provide the user with an indication that the desired tension has been reached. They are precision designs that have raised bump outs that contact with the bearing surface of the nut or bolts. These bump-outs are designed to collapse back into the surface of the washer when the designed tension value is achieved. Some of these are designed with silicon filling the depression created on the underside of the bump-out. When the material collapses back into the washer it pushes this silicon out providing a positive means of identifying that the bolt has achieved its

desired tension. These are known in the industry as "Squirters". The Material Standard referenced with these products is ASTM F959/F959M.

Finally, Section 6 of this standard provides detailed dimensional and general information required to produce Twist-Off Structural Bolts. Twist-Off Structural Bolts are an innovative designed bolt that has a nib on the end. They come in round head and hex varieties. Using a special installation tool the nut is driven on the part using the nib to rotate the bolt. Once a specified torque is reached, a groove designed with the nib allows the nib to shear off. In theory, if everything was done right and the torque-tension relationship is properly understood, the nib will separate when the desired tension is reached. It is important that installers be properly trained and daily test the structural fastener assemblies to be assembled to verify that the torque tension relationship is performing as anticipated. The Material Standard referenced with these products is ASTM F3125/F3125M Grades F1852 and F2280.

### ASTM Material Standards

In 2015 the ASTM F16 Fastener Committee completed the monumental task of combining six different structural bolt standards into one. The resulting document was ASTM F3125/F3125M. This standard combines all six previous structural fastener types into one document and identifies each by a Grade Designation; Grade A325, Grade A325M, Grade A490, Grade A490M, Grade F1582, and Grade F2280. This new standard encompasses both inch and metric designs. In essence, the Grade A325 and A325M versions possess tensile strengths of 120ksi and 830MPa, respectively. Grade A490 and A490M are higher strength versions, with tensile strengths of 150ksi and 1040MPa, respectively. F1582 and F2280 are the inch and metric versions of the twist-off structural bolt design. F1582 has a minimum tensile strength of 120ksi/830MPa and F2280 has a minimum tensile strength of 150ksi/1040MPa.

The nuts are governed by ASTM A563 which the general purpose standard for steel and alloy steel nuts and ASTM A194/A194M for steel and alloy steel nuts in high temperature service. The hardened, flat washers are covered by ASTM F436/F436M and the DTI washers by ASTM F959/F959M.

### Specification for Structural Joints Using High-Strength Bolts

The Research Council on Structural Connections maintains the "Specifications for Structural Joints Using High-Strength Bolts". The current revision of this standard is 2014, although a significant revision is currently in the works and should be released in the near future.

This document is considered to be the authoritative resource for anyone involved in the installation of structural fastener assemblies. It is a wealth of information and provides easy to understand guidance on the installation of structural fasteners. It is a very thorough document of almost 100 pages and ten sections consisting of information related to the components of the fastener assembly, joint requirements, installation, and inspection. Even if structural fasteners and their installation are outside of one's scope of everyday activities, a copy of this standard in your engineering library makes a great addition. It can be obtained at no cost on the council's website, [www.boltcouncil.org](http://www.boltcouncil.org).

### Summary

Structural fasteners are an exciting and interesting segment of the construction fastener segment. Although serviced by a relatively small group of suppliers, the applications are critical in nature and we all highly depend on these companies having the requisite knowledge of and ability to produce high quality product. There is a great deal written and available about structural fasteners. Hopefully, this brief summary helps to demystify some of the more confusing points. ■

